5.0 Past Management and Oversight Practices and Employee Relations

5.1 Oversight

The AEC, ERDA, or DOE have had a nearly continuous site presence at PORTS. The AEC had a local Portsmouth Area Manager performing contractor oversight. Records reflect some indirect ES&H-related oversight activities by the Area Manager, including communication of new or revised regulations and standards, transmittal of appraisals performed by OR, and communication of concerns related to events and reporting of off-normal conditions. Records reflect limited direct Federal ES&H oversight of Plant activities in the early years. OR appraisals of ES&H, called "contractor health protection program reviews," were performed as early as 1957, and the AEC manual required annual ES&H assessments starting in 1961. These assessments were generally performed by two persons over three days and addressed radiation protection, criticality safety, industrial hygiene, environmental programs (scrap metal and effluent discharges), and corrective actions in response to recommendations from prior reviews. Goodyear Atomic Corporation appears to have been responsive to AEC recommendations. Although important deficiencies and issues were identified by these reviews, the size and complexity of Plant operations and the nature of the industrial hazards and environmental concerns present warranted longer and more frequent assessments using more than two assessors. These reviews consistently concluded that the PORTS health protection program (including environmental controls) was satisfactory. A more in-depth, two-week assessment conducted in 1973 by OR included field observations of Plant conditions, work performance, and interviews with workers and first-line supervisors; it concluded that the health protection program at PORTS was inadequate. However, there was no further evidence of more rigorous assessments, and the limited annual appraisals resumed until the 1980s. Starting in 1975, OR performed annual OSHA inspections of PORTS. In the 1980s, OR conducted annual environmental assessments that evaluated air emission and water discharge control programs. These assessments were expanded to include hazardous waste management programs as regulations for TSCA and RCRA were promulgated. These assessments, combined with special reviews by OR environmental personnel, identified several significant environmental concerns, as discussed in Section 4.1. The annual environmental assessments were discontinued in the late 1980s.

The AEC performed detailed investigations of the more significant events (releases and accidents), and OR or Portsmouth Site Office personnel participated in many Goodyear Atomic Corporation investigations of less serious incidents. Generally, these investigations were thorough, and many included identification of ES&H issues and specification of detailed corrective actions to address root causes. However, the continuing problems over the first 25 years with process gas and fluorine releases and with contamination control indicate that the thresholds for acceptable performance were too low and implementation of corrective actions was ineffective.

The AEC and its successor organizations also investigated worker allegations of unsafe conditions and practices, but with inconsistent rigor and results. Many of these allegations surfaced at times of contention between Goodyear Atomic Corporation and unions. For example, worker complaints to DOE during an October-November 1977 investigation and in May 1978 regarding respirator usage and related training resulted in nine recommendations concerning safety meetings, electrical work permits, hazardous work permits, heat stress, eating in contaminated areas, training, operator certification, and personal protective equipment usage. From 1979 through 1982, another major DOE investigation of worker complaints, conducted at the direction of Congress, identified performance problems in a variety of ES&H areas.

Historical weaknesses in DOE investigation of worker allegations have continued to the present program. One case in particular, raised during the transition from DOE to NRC oversight of USEC, still remains unresolved. That case involves allegations by a Plant guard who maintains that, in 1994, he was exposed to fluorine, and that his radiation exposure records were falsified. Internal investigations by Lockheed Martin Utility Services found some merit to the allegation, and the allegation was forwarded to the Oak Ridge Operations Office Inspector General in 1996. That case remains inadequately investigated and unresolved by DOE.

In 1980, the General Accounting Office (GAO) performed a review of the DOE program for ensuring the safety and health of workers at the three uranium enrichment plants. GAO determined that program implementation was inadequate. This report acknowledged that safety statistics and radiation exposures were low compared to similar industries, but stated that ES&H oversight "is not approaching the coverage required by the program" and cited a shortage of safety and health staff at OR. Also cited were delayed and inadequate corrective actions for known contamination control problems that were not addressed until the union issued formal complaints. The DOE disputed the significance of GAO's concerns.

In the 1970s and 1980s, the DOE Headquarters Environment, Safety and Health organization performed technical safety appraisals of functional areas at approximately five-year intervals. In the 1990s, OR increased ES&H oversight appraisal activities by performing more detailed functional area appraisals and providing input to ES&H elements of the award fee contracting process. The current DOE Portsmouth Site Office was formed about 1988 with approximately eight technical staff members in various disciplines to oversee production activities and ES&H performance. The 1989 DOE Tiger Team assessment identified numerous health, safety, and environmental deficiencies; ES&H program weaknesses; and management issues. OR and the DOE Headquarters Office of Nuclear Energy performed increased functional area assessments until USEC assumed operation of the Plant in 1993. As discussed in Volume 2, DOE oversight of ES&H from 1994 through 1999 was limited to Portsmouth Site Office activities.

In summary, AEC-ERDA-DOE oversight of ES&H performance was not rigorous or proactive for much of PORTS history. Although this oversight was sometimes effective when vigorously exercised, such as event investigations or the Tiger Team assessment, consistency and follow-through on corrective actions were often lacking.

5.2 Labor Relations

Established in 1954, the Oil, Chemical, and Atomic Workers Union (OCAW) was aggressive in its efforts to protect and improve employee welfare. This aggressiveness sometimes caused friction between Plant management and labor. On numerous occasions, the positions of management and labor differed widely, and resolution was accompanied by extreme measures, as evidenced by one unauthorized and six authorized strikes that occurred from 1954 to 1993. Furthermore, the severity of management and labor disagreements appears to have increased beginning in 1974, as suggested by the frequency and duration of strikes. While economic issues were common to most strikes, safety and health were an important element in three of these seven actions, as summarized in Table 2.

Collectively, the number of grievances filed, worker compensation claims submitted, and alleged acts of retaliation committed provide further support that management and labor relations were strained. From 1954 through1993, it is estimated that more than 17,000 union worker grievances were filed addressing a variety of issues in addition to safety and health, including work jurisdiction, discipline, overtime, work rules, and benefits. A review of selected ES&H-related grievances filed during this period reveals that sometimes labor took issue with company actions that may not have been clearly defined by policy, and management responded to the aggrieved employees with ambiguous statements, thereby exacerbating what

1976 OCAW Strike

Table 2. Portsmouth Gaseous Diffusion Plant Oil, Chemical and Atomic Workers Strike History: 1954-1993

Strike Period	Duration	Type	Principal Reason(s)
October 3 - 4, 1956	1 day	Unauthorized	Responsibilities and Safety[a]
May 10 – 16, 1957	6 days	Authorized	Wages and Safety[b]
May 2 – May 20, 1969	18 days	Authorized	Wages[c]
May 2 – August 8, 1974	98 days	Authorized	Wages[d]
August 28 – December 13, 1976	106 days	Authorized	Wages[e]
May 3 – December 15, 1979	228 days	Authorized	Wages and Health[f]
June 11, 1991 – April 6, 1992	299 days	Authorized	Overtime and Requirements[g]

[a] Reason for the strike involved ten issues associated with work jurisdiction, employee responsibilities, treatment of grievances, showering time and facilities, seniority, overtime, safety, and uniform treatment between hourly and salaried employees.

[b] Reason for the strike involved 19 issues associated with employee fringe benefits, employee responsibilities, union contract language, safety and health program, and overtime.

[c] Reason for the strike involved issues associated with wages and contract language.

[d] Reason for the strike involved issues associated with wages and worker classification.

[e] Reason for the strike involved issues associated with wages, and medical and pension fringe benefits

[f] Reason for the strike involved eight issues associated with overtime, work responsibilities, contract language, wages, physical examinations, and fringe benefits.

[g] Reason for the strike involved issues associated with overtime administration, seniority, contract language, and following Department of Energy orders.

was already a strained relationship. For example, in February 1958, X-700 maintenance mechanics filed a grievance because they were denied cold weather outer garment contamination clothing (parkas) to control the spread of contamination when commuting to and from their assigned building or working outside. Management did not dispute the furnishing of parkas "to the extent they are available to control the spread of uranium contamination when employees on red job assignments are required to perform outside work." However, management stated that "beyond this basis for issuance, parkas are not within the scope of the clothing which the Company requires employees to wear for their own protection." Additionally, management stated that the "Company has not established either the policy or practice of furnishing parkas to all maintenance mechanics in the X-700 building when leaving or working outside that building." There are other instances in which communication between management and labor was ineffective. For example, a 1979 grievance was filed by an employee who received a memo from management for "coming into work [in the X-700 Building] without wearing safety glasses." Records indicate that there was a misunderstanding between union members and management on the wearing of eye protection in Buildings X-700 versus X-720. Safety glasses were required at all times in X-700, while this was not true for X-720.

In contrast to the previous examples, there are records suggesting that labor grievances were filed to be confrontational, as management appeared to have been acting appropriately and in the interest of its employees' safety and health. For instance, in 1976 an employee filed a grievance protesting being admonished formally by the company for failure to follow certain operating and safety procedures, including wearing required respiratory protection equipment. This grievance was denied, as the company considered its actions "extremely liberal in view of

[its] strong position on insisting that operational and safety procedures be complied with explicitly."

Worker compensation claims, which began to appear in the early 1950s shortly after Plant startup, also reveal discord between management and labor. Interviews with past and present employees and review of records indicate that there were allegations by employees that management would go to great lengths to deny or avoid compensation claims, including being untruthful and pursuing legal loopholes to avoid accountability. For example, workers claimed that Plant management would use sampling data taken from surveys performed hours or days after an alleged exposure to disprove safety and health injuries purported to have resulted from Plant operations. Additionally, there is evidence suggesting union distrust of Plant medical opinions, leading workers to obtain the services of certain community physicians to address their medical concerns. Consequently, disagreements between management and workers concerning exposure levels for radiation, metals, and chemicals were harsh and were often heatedly debated in correspondence and during compensation testimony. In many cases, it appears that the company started from an assumption that the exposure could not have resulted from work at the Plant, and then set out to prove its premise.

Records indicate that some employees, who had contracted illnesses like leukemia or other forms of cancer, filed compensation claims to request monetary compensation for their illnesses; in the case of death, their families filed lawsuits. Some of the claims lacked technical basis, such as a case of liver cancer developed by a Goodyear Atomic Corporation employee after a brief work history at the Plant and a long history of health problems. Correspondence between the Plant medical director, a family physician, and lawyers working on this case appeared to successfully explain the lack of any relationship between Plant exposure and the disease. Other cases were not resolved so easily, and some were "showcased" on the radio, television, and in newspapers. Some employees sought damages amounting to several million dollars, claiming loss of income and punitive damage; in cases where the employee died prior to settlement, surviving relatives continued the case.

The time, money, and expertise necessary to respond to worker compensation claims prompted the program to move from the medical department to the direct control of human resources management. External legal counsel was frequently added to defend difficult or complicated compensation cases. Discussions with a longstanding worker compensation program employee suggested that Goodyear Atomic Corporation, Martin Marietta Utility Services, and Lockheed Martin Utility Services were conscientious in following the State of Ohio workers compensation regulations.

The perceptions of some past and present employees indicate that raising safety and health issues, either by simple verbal complaints, filing formal grievances, or submitting worker compensation claims, was sometimes accompanied by management and peer retaliation. For example, an hourly worker filed a grievance in December 1978 maintaining that he was unjustly suspended for insubordination for failing to enter an area that he believed was contaminated despite the opinion of his foreman, who maintained that the area was uncontaminated. The union protested the suspension, and the grievance was sustained by an independent arbitrator.

The impact of management and labor discord on the Plant-wide safety and health program is two-fold. While alleged efforts by management to deny culpability in certain personal injury cases and authorized strikes by the union workforce may have heightened mutual distrust, the sheer number of grievances and workers compensation claims compelled the company to react and be more conservative in its approach to protecting its employees. The discord also created a heightened awareness among various stakeholders (e.g., the public and the Federal government), thereby prompting independent investigations into the safety of Portsmouth operations.

The other major union at the Plant, the United Plant Guard Workers of America (UPGWA), has had no strikes since its formation in 1955. Generally, protective force personnel appeared to be considered outside the Plant mainstream, despite the fact that they were integral to maintaining its security and were collocated with Plant operations. Interviews with some protective force personnel, combined with a lack of formal records, suggest that information on Plant hazards and associated safety precautions was insufficient, and this, combined with other factors, fostered the blind obedience exercised by the guard force in maintaining the security of PORTS. Interviews with various PORTS workers, in addition to historical photographs, provide some evidence suggesting that from Plant startup until the early 1990s, guard force personnel were generally unprotected from the hazards associated with the operations and products they were responsible for securing. Often guard posts were in close proximity to Plant workers who were wearing respirators while protective force personnel were not, or guards were at the scene of accidental releases without appropriate respiratory protection. Even as the balance of the Plant responded to new information on hazardous materials and EPA and OSHA safety regulations, protective force training lagged. Guards continued to conduct drills and practice in spaces and amongst equipment and products they were responsible for protecting that were sometimes radiologically and chemically contaminated. As the protective force received better information and training on Plant hazards and safety precautions in the mid- to late 1990s, they focused attention on obtaining answers and compensation from management for past and present personnel who had possibly been subjected to harm.

APPENDIX A
HISTORICAL HAZARDS

This appendix discusses the radiological, chemical, and physical hazards present at PORTS, and the potential effects of exposure to these hazards.

Radiological Hazards

The radioactive hazards associated with PORTS operations and supporting activities include uranium and its daughter products, transuranics, and fission products. From 1957 into the mid-1960s, numerous studies of the radiological effects of neptunium, plutonium, technetium, and other fission products and transuranic elements found low concentrations of these impurities in incoming reactor tails. However, the impurities tended to concentrate in certain areas of the oxide conversion plant, cascade, equipment, and process piping.

The policies in place at PORTS to protect personnel from the inherent hazards of handling radioactive materials were based upon preventing personnel exposures from exceeding the Radiation Protection Guides (RPGs) established by the Federal Radiation Council, the requirements of AEC manual chapters (subsequently ERDA and DOE orders), those established by the National Committee on Radiation Protection and Measurement (NCRP), and the National Bureau of Standards Handbook 69. The AEC policies in place at the time further encouraged the maintenance of radiation doses as far below applicable standards as was practical. The application of these policies from 1954 to 1990 and the expectation that employees would adhere to procedures and guidelines were essential factors in hazard identification and control at PORTS.

Uranium is a naturally occurring element in the earth and is mined for commercial purposes. Natural uranium is 99.3 percent uranium-238 (U-238) and 0.7 percent uranium-235 (U-235). U-235 is used as nuclear reactor fuel. Enriched uranium contains more U-235 and depleted uranium contains less U-235 than natural uranium. U-238 has a radioactive half-life (the period for material to decay to half of its initial radioactivity) of 4.47 billion years. Once in the body, uranium may concentrate in the kidneys, bones, or lungs, depending on its solubility. For insoluble forms, radiation dose to the lung is a predominant concern. The principal sources of internal uranium exposures at PORTS relate to the inhalation or ingestion of primarily soluble forms but include insoluble compounds in some areas, such as the oxide conversion (X-705E) and feed production (X-344) facilities. The maximum enrichment for PORTS until July 1964 was 97 percent. From July 1964 to 1991, the maximum enrichment for PORTS was 93 percent U-235. In the mid-1990s highly enriched foreign (French) fuel was down-blended (that is, its enrichment was reduced). UF_6 exists at PORTS as a gas, liquid, and solid. Other compounds of uranium, such as UF_4, UO_3, and U_3O_8, have been present in significant quantities in the feed manufacturing plant and the oxide conversion plant. There is evidence that workers were exposed to uranium in forms that could cause adverse health effects.

Uranium daughter products are produced when uranium decays by the emission of alpha radiation to produce other radioactive isotopes (called daughters). When uranium is melted or separated by chemical or physical means, less-dense daughter products, such as thorium-234 and protactinium-234m, can be concentrated. Further processing can leave significant quantities of these daughter products in oxides or ash, or on the surface of process vessels. Daughter products were present in varying amounts at the feed manufacturing plant fluorination towers (primarily from ash receivers and the sintered metal filter baths), in X-705 and X-720 from converter and compressor disassembly work, product feed/withdrawal stations, cylinder cleaning stations, raffinate from uranium recovery, in cylinder heels, and other areas of the cascade. The beta radiation dose rate from residual concentrated daughter products is much higher than from the original uranium. In addition, daughter products in the form of fine particulate (like dust) are easily transferred by contact. Exposure to daughter products from transfer to clothing, tools, or other items is likely to result in unanticipated beta radiation doses to workers. Protactinium-234m emits a high-energy beta particle, which contributes most of the beta dose from the uranium-238 daughter products.

Transuranic elements have atomic numbers greater than 92 (i.e., greater than uranium) and can be produced when U-238 absorbs neutrons as part of a nuclear reaction. The principal transuranic elements of concern are neptunium and plutonium. Both are alpha emitters that have very long clearance time in the body. Transuranic elements were introduced to PORTS from processed spent reactor fuel or from reuse of cylinders containing transuranic contamination.

- **Neptunium-237** has a radioactive half-life of 2.14 million years and is far more hazardous than natural uranium. The specific radioactivity of neptunium-237 is 2,000 times higher than the radioactivity of depleted uranium. The low concentration of neptunium found in reactor tails feed material was not a significant radiological hazard, and at such levels the controls for uranium would protect personnel from exposure to neptunium. However, neptunium concentrated at certain points in the uranium conversion, enrichment, and recovery processes. The highest concentrations were associated with oxide conversion and the waste streams associated with that process (X-705E and X-701B).

- **Plutonium-239** is significantly more radioactive than neptunium but is less a hazard at PORTS because it was present in much lower concentrations. It has a radioactive half-life of 24,065 years. Once plutonium reaches the bloodstream, it accumulates primarily in the liver and skeleton. Plutonium exposure may produce acute health effects (e.g., ingestion may lead to damage to the walls of the gastrointestinal tract) or long-term effects, such as increased risk of cancer. When plutonium is inhaled, the lungs are exposed to alpha-particle radiation, increasing the risk of lung cancer, and the plutonium is eventually carried to other organs where the radiation can cause cell damage and increase the likelihood of biological effects. Recent estimates indicate that there was only a small amount of plutonium in the uranium fed into the PORTS cascade; plutonium concentrated in the oxide conversion facility. Because it remained in the ash material, most was removed with the ash residues and particulate filters in the conversion of uranium oxides to UF_6. Individuals most likely exposed were those changing particulate filters and emptying the ash collectors. There were small quantities of plutonium in the cascade feed areas, which could have had the potential for exposures during CIP/ CUP activities.

Fission products are formed when neutrons split uranium-235 atoms during a nuclear reaction. They typically have atomic numbers in the range of 80 to 108 and 125 to 153. The predominant fission product of concern at PORTS was technetium.

- **Technetium-99** is a weak beta emitter with a radioactive half-life of 213,000 years and was introduced at PORTS in recycled reactor feed. The primary exposure pathways are ingestion or inhalation. Protective clothing would adequately shield the low-energy beta particles emitted by technetium. Technetium passed through the Paducah cascade as a volatile compound of fluorine, depositing on internal surfaces of the cascade and contaminating the uranium product. Similarly, technetium at PORTS contaminated many areas, including cascade equipment. The AEC did not specify a limit for technetium in UF_6 feed but controlled the concentration of technetium indirectly to about 10 ppm by limiting gross beta due to fission products. In addition, some customers established a 10 ppb limit on technetium in product cylinders. There was evidence that workers had some exposure to technetium.

Chemical and Toxic Metal Hazards

The PORTS operations exposed workers to a wide variety of chemical and toxic metal hazards. Some of these hazards and their health effects were known from the early years of the Plant's history, such as mercury, fluorides, carbon tetrachloride, and TCE. However, the hazards of some substances, such as PCBs and asbestos, were not recognized until the 1970s. As knowledge of the health effects of hazardous chemicals increased, permissible exposure levels have generally decreased. Accordingly, many of the limits established in the 1950s would not be acceptable today. The issuance of the OSHA hazard communication standard in 1983 drove improvements in chemical hazard identification at PORTS. The hazard communication standard required identifying chemical hazards, labeling chemicals, documenting a chemical hazard program, training workers, and most importantly requiring that manufacturers develop and disseminate Material Safety Data Sheets (MSDSs) to chemical purchasers. The following paragraphs summarize the principal hazards of toxic metals, gases, and solvents that PORTS workers were exposed to during the period of 1952 until 1997.

Uranium radiation hazards are discussed above. As a heavy metal, uranium is toxic and can damage the kidney. Both the solubility and enrichment determine the toxic chemical effects. In 1987, the National Institute of Occupational Safety and Health (NIOSH) completed a study to assess the risk of cancer mortality associated with exposure to uranium compounds at the Plant, particularly uranyl fluoride, the most prevalent compound of exposure interest. The study concluded that the workers at PORTS had experienced excess stomach cancer and excess cancer of the hematopoietic system, which included leukemia. However, the study also concluded that these excesses were not statistically significant, because they occurred in a group of workers who demonstrated less overall mortality than the U.S. population in general. (NIOSH is updating this study, and results are expected before the end of calendar year 2000.) Uranium chemical exposures have been monitored at PORTS since Plant startup. Routine bioassays were conducted as early as the 1950s, and air sampling was performed throughout the history of the Plant.

Beryllium is a silver-gray metallic element used as pure metal, as beryllium-copper and other alloys, and as beryllium oxide. Beryllium is useful in manufacturing due to its strength, light weight, machinability, and relatively high melting point. The severity of health hazards resulting from even minimal contact with beryllium is only now being fully understood. Beryllium can enter the body through inhalation, skin absorption, skin wounds, and ingestion. The most serious health effects come from inhaling airborne insoluble particles that deposit in the lungs. Chronic beryllium disease, which occurs in one to six percent of exposed workers, has a latency period of up to 20 years and has no known cure. There was limited evidence of incidental use of beryllium at PORTS. Besides the use and/or disposal of sealed plutonium-beryllium neutron sources, one stores department worker indicated that he had stocked beryllium bars, which were sent to the X-720 machine shop. Another worker and a supervisor believed they might have machined small quantities of beryllium in the same shop in the mid-1970s. Beryllium at PORTS may have included incidental machining of beryllium copper-alloy process piping components, such as valves. Some tools plated with beryllium were also used. Other beryllium use may have included use and disposal of fluorescent light bulbs containing beryllium oxide and use of beryllium-containing welding rods until the mid-1990s. The site routinely sampled for beryllium in the environment in the early 1990s, and detectable beryllium concentrations above background were identified in several areas at PORTS.

Arsenic exists in organic or inorganic forms, and all are toxic. Non-occupational exposure to arsenic can also occur from drinking water, food, polluted air, and cigarettes. Symptoms of chronic arsenic poisoning include illness and fatigue, with stomach and intestinal distress. Arsenic is a carcinogen, causing increased risk of skin, liver, and lung cancer. Arsenic has been identified in several areas in the Plant, including the X-342 fluorine generators, X-326 process gas, converter maintenance in X-700, wood preservatives in the cooling towers, and coal and coal byproducts in the steam plant. In 1993, arsenic was first discovered in X-326 process gas that resulted from arsenic-contaminated UF_6 feed material. A March 1994 NIOSH evaluation of worker exposures to arsenic in the process system concluded that concentrations were generally below detectable limits. Only one of the 600 air samples taken during this study was above the OSHA limit. Arsenic also naturally occurs in coal and accumulated in the boilers of the PORTS steam plant. Utility personnel, who routinely removed scale from boilers, were unaware of an arsenic hazard until the potential for it was identified in a notice from OR in the late 1980s. Subsequent sampling indicated that arsenic concentrations exceeded limits by factors of 10 to 100. Consequently, workers shifted from dust masks to air-supplied respirators for descaling. Arsenic was also present in fly ash, but the concentration was much lower than the concentration in firebox scale. Ash was routinely buried in an onsite landfill, used on site roads, and placed on a track at a local high school. Use of fly ash for this purpose is a common industrial practice, and not unique to PORTS. Toxicity tests of the fly ash in the early 1990s demonstrated that it did not meet RCRA criteria for hazardous waste. Since that time, however, fly ash and scale material have been returned to the coal mine by the coal contractor. The health effects for workers exposed to arsenic, especially in the process system, are indeterminate. General exposure levels were low, but in some cases the presence of arsenic was not recognized. In the steam plant, exposures could have exceeded limits, as is the case in all industrial coal-fired steam plants.

Mercury exists as an element (metallic) with inorganic and organic forms. Early symptoms of mercury poisoning include salivation and tenderness of the gums. Mercury vapor can reach the brain cells, where it is oxidized to produce toxic effects. The major effects of chronic exposure to mercury vapor are on the central nervous system, resulting in increased excitability and tremors. Chronic elemental mercury symptoms are slow to develop and difficult to diagnose. Inorganic mercury salts, such as mercuric chloride, often cause skin problems and can result in extensive kidney damage. Organic mercurials, such as methyl mercury, can cause severe birth defects or mental retardation. Health effects of mercury were known as early as the 1950s. As early as 1955, PORTS bulletins contained precautions for avoiding mercury poisoning.

The principal uses of mercury at PORTS included thermometers, manometers, chemical traps, vacuum pumps, switches, and fluorescent lights. Manometers were used to measure differential pressures, flows, and absolute pressure. Line recorders (spectrometers) used mercury in chemical traps to remove UF_6 from sample streams to allow detection of low molecular weight gas contaminants contained in the process gas. Diffusion vacuum pumps were used to sustain vacuums necessary for proper operation of assay and line recorder spectrometers. Mercoid switches that contained mercury and large manometers (reported to contain pounds of mercury) were initially filled and refurbished in the X-710 and the X-720 Instrument Shop. One interviewee remembered having to reclaim several hundred pounds of mercury stored in a hood. In the 1950s and 1960s, recovery operations involved mercury distillation in the X-705 recovery area. In those years, cleanup reportedly involved brushes and dustpans for retrieval by workers wearing Army assault masks and rubber gloves. However, some former workers who were interviewed reported experience with mercury spills inside and outside buildings and handling open containers of mercury without any type of personal protective equipment. In the 1960s and 1970s, airborne mercury levels greater than PALs were identified in the instrument shop cleaning room after a spill. Chemical trap cleaning before the 1980s reportedly involved flushing, resulting in saturating a small ground area with mercury. Later, mercury vacuum cleaners and Mercury-X (a specialized cleanup product) were utilized for cleanup. In the 1980s, efforts were made to reduce mercury on site, and recovery in X-705 ceased. Evidence indicates that mercury was a significant hazard to workers from the 1950s to the 1980s. During the 1970s, a monthly Industrial Hygiene and Health Physics report had a separate section for reported mercury spills for the month. Overall, mercury was handled extensively, sometimes without adequate personal protective equipment, and could have had adverse health effects on workers.

Lithium is intensely corrosive and may produce burns on the skin from the formation of the hydroxides. Like most toxic metals, chronic exposure to lithium at elevated levels can result in impaired functioning of the kidneys, changes in blood pressure and blood volume, and neural and hormonal effects. From the early 1960s, 187,000 drums of lithium hydroxide monohydrate (LiOH) were stored at PORTS in five warehouses. The LiOH was transferred from OR for storage at PORTS. The LiOH stored at PORTS also contains 2-15 ppm mercury. Originally, lithium was in 55-gallon fiberboard drums, which corroded over time, spilling some of the contents on warehouse floors. During the late 1970s, a significant Plant project involved the cleanup and relocation of the lithium, moving the drums, and dismantling and moving the warehouses to provide space for the construction of the gas centrifuge plant. According to some workers interviewed, the LiOH dust during drum relocation was sometimes so thick that the lights of the forklifts were hard to see. Although dust masks were worn by some, respirators were not required. Several workers who participated in this project complained of ill effects, including high blood pressure and increased occurrence of cardiovascular ailments.

During the mid-1980s, a significant Plant project involved the overpacking of the LiOH because the warehouses in which it was stored were leaking from rain events, causing deterioration of the fiberboard drums. The 55-gallon fiberboard drums were overpacked into 85-gallon drums, and the roofs on the five warehouses were repaired. Use of the 85-gallon drums required additional warehouse space; therefore, two additional warehouses were constructed on the hill on the west side of the reservation, overlooking the perimeter road, to handle the overflow. Today, the inventory is less than half of the original amount. A commercial contractor is gradually removing the product off site.

Chromium salts are irritating and destructive to tissue. Mists from electrolysis baths and plating baths cause dermatitis and damage to nasal membranes. Problems extend to the respiratory tract when dusts, fumes, or mists are inhaled. Because of the toxic nature of plating bath contents, disposal must be done carefully to preclude serious environmental damage. Chromium and chromium compounds were used throughout the Plant's history in electroplating operations and as an anti-corrosion inhibitor in recirculating water systems.

In the mid-1950s and later, sodium dichromate was added in considerable quantities to the recirculating water system, primarily as an anti-corrosive agent. For example, during one week in 1956 three trailer loads of sodium dichromate were received at Stores, totaling 160,000 pounds. Sodium dichromate typically came in 100-pound paper bags, some of which ruptured during transport. On one occasion, a worker filed a written complaint alleging that several workers had been treated in the hospital for overexposure to sodium dichromate. Industrial hygiene personnel concluded that three workers had been overexposed, as evidenced by nasal irritation experienced by the workers, and that the protective clothing at the beginning of the job was less than adequate. The Safety and Industrial Hygiene Department issued a Safety Letter, advising workers of the hazards of sodium dichromate and chromic acid and indicating the appropriate personal protective equipment. While the long-term health effects are not well known, some workers have been exposed to chromium compounds from plating operations, transport, addition of dichromates to water systems, and during maintenance of those systems.

Nickel metal is a hard, silvery solid with a high melting point. Nickel carbonyl, a volatile liquid and a very toxic gas, is the most acutely toxic nickel compound known, causing immediate poisoning, hemorrhagic pneumonia, and delayed lung effects. Nickel-plating workers can suffer from dermatitis caused by skin contact with nickel salts. Nickel compounds also can cause chronic eczema. Some individuals are susceptible to becoming sensitized to nickel, and once sensitized, they respond even to contact with nickel alloys. In industry, nickel-plating workers and welders exposed to various nickel compounds have developed allergic lung reactions, such as asthma; loss of the sense of smell; and severe nasal injuries, such as perforated septa and chronic sinus infections. Increased susceptibility to respiratory infections is also possible.

At PORTS, nickel-related operations were performed in several areas of the Plant. Worker exposure to nickel was possible during welding, cutting, or grinding on nickel-containing components, and during nickel spraying operations in X-720. Nickel sulfate crystals and nickel chloride were used in nickel plating operations in X-720 during the mid-1950s and later. In 1973, nickel welding fume concentrations were measured in the X-700 converter shop, X-720 weld shop, and the X-705 seal dismantling booth and were well above limits. In addition to nickel welding and plating, grinding operations on nickel-plated tube sheets and process gas pipe flanges were common throughout the Plant's history. One of the more hazardous operations involved nickel spraying. A 1982 industrial hygiene survey of nickel spraying in X-720 identified airborne nickel concentration up to 15 times the limits. Consequently, personal protective equipment was improved to require supplied-air respirators, company-supplied welder's coveralls, leather gloves, and face shields or welder's glasses. In 1980, a feasibility study to reduce airborne nickel was performed, resulting in improved ventilation systems. In 1991, NIOSH expanded a previous 1987 NIOSH study on worker exposures at PORTS by considering worker exposures to fluorides and nickel. The results of this study are to be published by the end of calendar year 2000. In general, although many workers were exposed to nickel fumes/mist (some of which exceeded permissible exposure limits), most workers were informed and usually wore personal protective equipment to mitigate the hazard,

Fluorine is a pale-yellow to greenish gas with a pungent, irritating odor. **Hydrogen fluoride**, or hydrofluoric acid (HF), is a colorless gas or fuming liquid with a strong, irritating odor. Exposure routes include inhalation, skin absorption (liquid), and skin and/or eye contact. Exposures can result in a variety of symptoms, ranging from irritation of mucous membranes to severe burns. The primary sources of exposure to HF at PORTS involve the opening of normally closed systems that are used to process UF_6 or generate fluorine gas, leaks, or process upset events. Fluorine was used in the oxide conversion and feed manufacturing processes and was generated in X-342. Fluoride hazards were identified early in the Plant's history.

Although the potential for exposure to fluorides at PORTS is widespread and involves many workers, documented overexposures have been infrequent. For decades, the industrial hygiene and safety group has maintained airborne and biological monitoring programs for fluorides. The biological monitoring program consisted of routine and special urinalysis to determine fluoride content. Routine urine samples were submitted on a frequency consistent with expected exposure frequency and concentrations, but typically on a monthly basis. In case of a probable exposure, special samples were obtained within a few hours after the event. Short-term air grab samples, area air samples, and personal breathing zone samples have been used to determine HF concentrations during work activities and to determine respiratory protection requirements. Workers at PORTS seldom exhibited urinary fluoride levels above limits. The highest recorded fluoride exposure level at PORTS was 45 mg/liter from the urine of a supervisor who had entered a fluoride release cloud without proper respiratory protection. Another worker was diagnosed with fluoride poisoning following exposure to UF_6 in 1984 at the high-assay sampling station. Before and after the X-326 stack extension in 1981, numerous workers complained of high fluorine levels causing nausea and nasal, throat, and eye irritation. Industrial hygiene sampling seldom identified concentrations above permissible limits; however, the gas dispersed rapidly, and samples may not have been representative of what workers were exposed to. A 1969 report identified HF concentrations of 3 ppm or greater outside X-705. Additionally, former worker interviews indicated that there were many releases where samples may not have been taken and where workers did not report to the Medical Department. In the early years of operation, there were a number of HF burns, and workers experienced symptoms similar to those described above.

Chlorine, at atmospheric conditions, is a greenish-yellow, non-combustible gas having a density about 2.5 times that of air. Its disagreeable and suffocating odor, as well as the irritation it causes to the nose and throat, generally warns even unwary persons, thus enabling them to escape substantial exposure. Chlorine was used in water and sewage treatment systems as a disinfectant. Industrial hygiene records indicate routine sampling for chlorine, such as the Chlorine Room in X-633. **Chlorine trifluoride** is a powerful oxidizing agent, igniting many organic compounds on contact, and it reacts violently with water. At room temperature and pressure, chlorine trifluoride is a colorless gas having a density of 3.14 times that of air. Chlorine trifluoride is extremely corrosive to tissue, and any contact with skin or eyes will typically result in severe damage. Its reactivity led to its use as a fluorinating agent in Portsmouth processes. Chlorinated compounds and chlorinated reaction byproducts were produced from the cascade process. The potential exposure of X-326 security guards to chlorinated compounds, among other factors, led to a NIOSH health hazard evaluation.

Welding has always been a common and continuing work activity at PORTS over the years, and there is a wide degree of variation in the degree of hazard that workers experienced on the job. The hazards to the eyes and skin due to sparks and fragments of hot metal were well recognized, and welders were usually well protected with face masks, gloves, and other protective clothing, including flame retardant coveralls in later years. However, the dangers from chemical exposure were not as well recognized. The type of fumes from welding depends on the metal being welded and the type of welding rod. Arc welding and plasma cutting produce irritating and oxidizing ozone gas. Degreasing fluids can remain on the metal, resulting in additional vapors. In addition, paints, grease, and other coatings may be burned and volatilized.

PORTS industrial hygienists have analyzed welding fumes since the 1950s. For example, a 1954 inspection of the machine and welding shops in X-720 identified a variety of welding fumes from welding on metals coated with cadmium, lead, mercury, and zinc. The welding included the use of fluoride welding fluxes that produced nitrogen oxides as well. One record dated in May 1957 identified significant levels of nickel and ozone in fumes from inert gas welding and heliarc welding in X-700. In 1959, elevated levels of phosgene were detected in the breathing zone of welders in X-720. In all of these early cases, ventilation requirements were evaluated, and respirators were recommended to control the hazard. A review of welding areas by Industrial Hygiene in 1973 identified nickel, uranium, copper, and iron oxide contaminants in steel metal inert gas welding in the X-720 welding shop. A Plant inspection in 1973 identified the use of cadmium and lead solders, without prior testing of local exhaust systems or without air samples to assess worker exposures. Union safety meeting minutes between 1972 and 1975 identified numerous complaints of shortages of company clothing and respiratory equipment, especially for welders.

Welders also fabricated, modified, joined, cut open, and repaired leaks on Freon systems, both within the process buildings and in X-700. The systems and components were usually drained and evacuated before cutting or welding; however, these controls were not always effective. One former worker described getting severe headaches while welding in high concentrations of Freon fumes without a respirator in the late 1970s. An Industrial Hygiene and Health Physics report addressing workers' complaints about cutting out

Freon piping in 1980 documents the exposure of eight workers to phosgene, hydrogen chloride, hydrogen fluoride, and Freon at levels exceeding safe limits. The workers had complained of a blue flash and irritating fumes. The problem appeared to result from a leaking hydrostatic test boundary valve in an adjacent cell. Welding fumes presented a variety of potential health hazards to workers from the 1950s through the 1980s. Most welding hazards were recognized and evaluated by industrial hygiene personnel, and respirators were prescribed. Some workers, however, were most likely exposed for short periods to fume concentrations greater than permissible limits, with potential for health effects.

Hydrogen cyanide gas, when inhaled, or the ingestion of cyanide salts, leads to cyanide poisoning. Cyanide has a characteristic "bitter almonds" odor that can aid in diagnosis. However, a significant percent of the population is genetically incapable of detecting this odor. Therapeutic treatment must be initiated immediately to be life-saving. At PORTS, both cyanide salts and solutions have been used by instrument mechanics engaged in copper and silver cyanide plating. Cyanide salt solutions and cyanide waste solutions were stored in toxic lockers in the instrument decontamination area of X-720. In 1982, Industrial Hygiene investigated the feasibility of installing a cyanide monitor to continuously sample cyanide fumes from silver plating operations. A 1980 memorandum from Industrial Hygiene stressed the importance of minimizing the onsite inventory of cyanide, and that large-scale plating operations should be avoided. Industrial hygiene personnel also required gloves, aprons, and face shields when working with cyanide waste solutions. A cyanide medical kit and a safety shower were required to be in the vicinity of any work involving cyanide solutions, waste, or salts. In most cases, cyanide storage and use appeared to be well monitored and controlled throughout the Plant's life.

Trichloroethene is a colorless liquid with a chloroform-like odor that is used as an industrial degreaser. TCE is a mild irritant to the respiratory tract and the skin, and is considered a potential carcinogen based on animal studies. Critical exposure pathways are inhalation, ingestion, and skin or eye contact. TCE concentrates in the respiratory system, heart, liver, kidneys, central nervous system, and skin. At PORTS, TCE became the solvent of choice in the 1970s and early 1980s. Large components were frequently cleaned in one of several vapor degreasers located in X-705, X-700, and X-720. Leaking vapor degreaser lids causing vapors and high TCE concentrations prompted a ventilation project for the building in the mid-1990s.

In the 1950s and later, bulk TCE and carbon tetrachloride were available at several locations at PORTS for dispensing to smaller containers for transport and use in hand-cleaning parts and surfaces, both in the shops and in the field. At least one interviewee remembered others using TCE to clean PCB-contaminated oil from their skin. Instrument mechanics remembered using TCE to clean control valves in the X-720 Instrument Shop and disposing of waste TCE by dumping it out the back door. The Instrument Shop also had an ultrasonic cleaner in their standards room that used TCE for degreasing. However, in response to complaints about the vapor, the unit was later removed.

A 1976 Industrial Hygiene and Health Physics report summarizing the hazards of TCE in welding areas described an incident near the X-720 Compressor Shop where airborne concentrations of TCE exceeded 700 ppm (maximum permissible concentration is 150 ppm). This occurred when an operator sprayed a suspended part with TCE over a vapor degreaser. This practice was reportedly in violation of previous recommendations. The report noted that if a welding unit had been operating in the area, which was often the case, dangerous and even fatal concentrations of phosgene could have been produced; ultraviolet rays from the welding arc can react with the chlorinated solvent vapor to produce phosgene gas. A 1980 Industrial Hygiene and Health Physics report documents the investigation of worker complaints of noxious odors while welding in the X-700 converter shop. Sampling identified TCE and phosgene in the immediate vicinity of the welders. A subsequent investigation determined that the ventilation system was not operating properly and did not provide sufficient exhaust from the chemical cleaning area to prevent TCE vapors from flowing into the converter shop.

Former workers remembered being taught not to breathe in or smoke around TCE vapors and to wear a respirator when degreasing. X-700 vapor degreaser procedures from the period 1958-1988 do not mention the use of respirators. A 1980 Industrial Hygiene and Health Physics report documents monitoring TCE concentrations during the hand-cleaning of small parts with TCE in the X-700. Based on continued problems with TCE vapor in the degreaser area, a project was funded to upgrade the ventilation. Historical evidence indicates a significant exposure to a large number of workers using TCE in several facilities, some without appropriate protection. In the late 1980s and early 1990s, as efforts were made to improve environmental programs, the use of bulk TCE was phased out and the vapor degreasers were emptied.

Other **chlorinated hydrocarbon solvents**, such as carbon tetrachloride and methylene chloride, have been used as degreasing solvents. Chlorinated hydrocarbons cause skin irritation due to the removal of skin oils, and they are central nervous system depressants. Carbon tetrachloride is absorbed readily through the skin or lungs and produces kidney and liver damage on continued exposure. Methylene chloride is a central nervous system depressant, and when metabolized in the lungs produces carbon monoxide, which readily combines with blood hemoglobin and restricts the body's uptake of oxygen. In 1980, a worker complained of lightheadedness while degreasing a compressor with a solution containing 20 percent methylene chloride. Several former workers described using carbon tetrachloride to clean the insides of equipment before initial operations, and subsequently cleaning up dust and deposits inside converter shells with a bucket of carbon tetrachloride and a sponge. Interviewees also asserted that they did not understand the hazards of these chemicals, used no respirators or gloves, and would frequently wash their hands in these cleaning agents.

Aromatic hydrocarbons were in frequent use at PORTS, but generally in lesser quantities than the chlorinated hydrocarbons. Benzene, for example, was a common industrial solvent used in the X-720 electrical and instrument maintenance shops in the mid-1950s. Benzene is volatile, and extended exposure to the vapors causes damage to the central nervous system, the gastrointestinal tract, and bone marrow. Prolonged exposure has been linked to an increased risk of cancer, particularly leukemia. A 1955 internal memo notes that "the use of benzene should be avoided whenever possible by substitution of a less toxic solvent." Benzene was also a common component of paints in the 1950s, and painters in the sign painting shop were cautioned on its use. It was evident that many workers were exposed to these solvents, and some had little knowledge of or regard for the short-term or long-term health effects.

Physical, Biological, and Common Industrial Hazards

Since the 1950s, line management has made a conscientious effort to identify and quantify worker hazards at PORTS, commensurate with the understanding of those hazards at the time. Asbestos has been a significant hazard at the Plant since construction. However, the hazards associated with asbestos were unknown, and efforts to sample and quantify airborne levels of asbestos were not initiated at PORTS until the 1970s. Throughout the decades, hazard identification resulted in changes in PORTS facilities, processes, and procedures to reduce or eliminate the hazard. However, there are numerous documented cases of inadequate procedures and procedural non-compliance by workers and supervisors, including monitoring, which show that these practices were common.

Polychlorinated biphenyl (PCB) is a colorless to lightly colored, viscous liquid with a mild odor. The critical pathways of exposure are inhalation, ingestion, and absorption. When humans are exposed, PCBs can affect the skin, liver, central nervous system, and respiratory system.

PCB-based oils were used at PORTS, for their stability, fire resistance and dielectric properties, in many power transformers and industrial capacitors. Until the early 1970s, these oils were periodically filtered and de-sludged, with the resulting filtrate and contaminated filter material disposed of on site. PCB oils were also used in pole-mounted transformers, synchronous condenser grounding transformers, fluorescent light ballasts, and certain oil-filled capacitors. PCB contamination was also determined to be present in cascade lubricating oil and hydraulic systems as early as 1980. During 1983, workers were informed that PCB oil contamination had been identified in the black caulking on cascade cell and unit bypass housings. PCB contamination from oil leaks was subsequently identified on other equipment, such as electrical cabling and local control center gaskets. Procedures for handling, storage, and disposal of PCB-contaminated oils were in place as early as 1977, specifying use of neoprene gloves and aprons, safety glasses, and disposable coveralls worn over regular fabric coveralls. Full-face respiratory protection was recommended when splashing was possible. Respirators were not deemed necessary, except in confined areas with large spills or when the PCBs were heated above 55 C. Because of the hazards, additional controls were placed on handling, cleaning, and disposal of spills, leaks, and waste oils.

In 1982, PCB was discovered in the gaskets in process building ventilation duct joints. The PCB contamination from ventilation ducts was carried by oil droplets from process motors to the floor of the process buildings. Therefore, management initiated a cleanup in 1983. In the late 1980s and early 1990s, PORTS installed troughs on leaking ventilation duct joints and connecting manifolds to collect PCB-contaminated oil, prevent the spread of contamination, and assure appropriate disposal. Results of limited blood sampling of workers potentially exposed to these PCBs found only two workers with measurable levels, both reportedly less than permissible exposure limits. However, it is likely that exposures were higher based on the extensive handling of PCB-contaminated oil and the lack of precautions early in Plant life. In 1990, PORTS established and began implementing a comprehensive PCB Program Management Plan. Many components previously containing PCB-contaminated oils have since been replaced or flushed to remove PCBs. Exposure to PCBs was pervasive for some work groups. Throughout industry, including PORTS, the hazards and controls for working with PCBs were not known until the 1970s. Some workers most likely were overexposed, with unknown long-term health effects.

Asbestos, as airborne fibers, can be inhaled or swallowed, and these fibers can become embedded in the tissues of the lung and digestive system. Once the fibers become trapped in the lung's alveoli (air sacs), they cannot be removed. In industry and construction, years of exposure to asbestos has caused a number of disabling and fatal diseases, including asbestosis, an emphysema–like condition; lung cancer; mesothelioma, a cancerous tumor that spreads rapidly in the cells of membranes covering the lungs and body organs; and gastrointestinal cancer, caused by ingesting asbestos-contaminated food. Like PCBs, identification of asbestos as a hazard did not emerge nationally or at PORTS until the 1970s or later. Before the 1970s, asbestos was widely used at PORTS because of its resistance to heat and corrosive chemicals. Asbestos was used extensively for construction, welding, and insulation since Plant construction. Asbestos was also used in cooling tower structures, duct curtains, expansion joint coverings, building siding, and by workers for protection against heat and weld splattering. Several former workers reported cutting asbestos blankets to size without any respirators or gloves. To work in hot areas or on hot pipes, workers would lie on asbestos blankets with large fans blowing air across the freshly cut asbestos blankets. This occurred in the late 1970s in X-333 and X-330. A number of PORTS workers in the 1950s to the 1970s were exposed to asbestos without knowledge of the hazards. The first asbestos control procedure was issued at PORTS in 1980. During 1980, divisional asbestos control managers were also assigned. Few controls were in place during the early decades, and the full extent of the long-term health effects is unknown.

Dust, noise, and illumination pose industrial hazards at PORTS. Many workers were exposed to high nuisance particulate (dust) concentrations and excessive noise from machinery; in some cases, work was performed in areas with poor illumination. These hazards were well recognized in the early years of the Plant. Monitoring by Industrial Hygiene often resulted in modifications to facilities and equipment. For example, in 1955 Plant industrial hygienists evaluated the impact of proposed modifications to the cascade buildings on the available lightning. A 1974 appraisal by OR identified that workers were exposed to more noise than was previously recognized, and that administrative controls (i.e., restricting workers' time in high noise areas) was not an adequate policy in lieu of issuing hearing protection devices to workers. Despite improving controls, historical documents indicate that many practices led to excess worker exposure to dust, noise, and other common industrial hazards.

Fungicides and biocides have also used been used at PORTS. Fungicides were used as an organic material preservative. Fungicides and pesticides can enter the body through ingestion, inhalation, and absorption pathways, with inhalation and skin absorption being the primary concerns. Health effects vary from minor headaches and nausea to debilitating conditions of the central nervous system.

The water for PORTS cooling towers was originally treated with sodium dichromate, sulfuric acid, and chlorine. Safer chemicals, such as phosphate and bromine-based dry chemical additives, were later substituted for the chromates and gaseous chlorine, to reduce environmental impact and enhance worker safety. Utility operators sprayed fungicide by climbing within the cooling tower structure on ladders and work platforms while dressed in protective clothing and breathing apparatus. The interior surfaces were coated with the dilute fungicide-water mixture. Steam sterilization in combination with several fungicides was utilized in 1962 and 1963 to rid the cooling towers of fungal colonies. Procedures from as early as 1961 specified protective equipment of Graylite (plastic suits) or equivalent, Graylite hoods, and neoprene gloves and boots. The 1982 version of the procedure allowed mixing with neoprene gloves and a dust respirator, but required full respiratory and outer garment protection for rinsing. Reportedly, one operator on the tower acted as a safety observer, a second operator on the tower did the spraying, and a third operator on the ground mixed the chemicals. Interviewees remembered that the safety observer and the ground person wore paper dust masks before the mid-1970s, and respirators thereafter.

Reviews of Industrial Hygiene and Health Physics records and discussions with long-time employees did not identify evidence of chemical exposure monitoring while spraying fungicides and algaecides in the cooling towers. Former carpenters interviewed expressed concern for the green dust generated during cooling tower repairs and the rotted and ice-damaged wood during the early period when they did not wear respirators. They assumed that the dust contained chromates, but the inspection team identified no monitoring data to reflect the materials and concentrations to which the carpenters might have been exposed. An industrial hygiene survey in November 1976, addressing the mist of an operating cooling tower, determined that all chemicals for which they analyzed were below established limits. However, this sampling may have no correlation to concentrations possibly encountered during spraying or cutting cooling tower wood with power saws.

Cooling tower operating procedures from as early as 1984 required respiratory protection against the possible presence of bacteria while working on top of an operating tower and within heavy mist. The principal concern is Legionnaire’s Disease bacteria (LDB), a naturally-occurring bacterium that has been monitored in PORTS cooling towers since 1979 and has on occasion reached potentially infectious levels. Control of LDB was implemented with halogen shock treatments, and with a control level well below assumed infectious levels. Earlier versions of the procedure also referenced concern for asbestos fibers, first detected in the cooling towers in 1975 and derived from asbestos-bearing fill material. Following asbestos abatement in the late 1980s and early 1990s, cooling tower fiber levels have dropped and are no longer a concern. Interviewees remember not wearing respirators on the towers in the early years and saw the change in requirements as an improvement in safety. The hazards associated with fungicides and biocides were identified, monitored, and controlled for some workers (e.g. cooling tower sprayers), but not for all workers (e.g., carpenters).

APPENDIX B
PRINCIPAL ACTIVITY EVALUATION SUMMARY

Table B-1 outlines the principal activities conducted at PORTS between 1952 and 1997, and provides an assessment of the hazards that may have been encountered by these activities, the controls available and generally used to mitigate the hazards, and the effectiveness of the controls when implemented. Acronyms are defined at the end of the table.

Table B-1. Portsmouth Gaseous Diffusion Plant Principal Hazardous Activity Evaluation Summary: 1952-1997

Activity Description	Plant Location(s)	Potential Hazard(s)	Hazard Control(s)	Hazard Control Effectiveness and Use	Time Period
Ash handling	X-344, X-705E	RAD, exposure to UF_6 gas, and inhalation of dust containing uranium and concentrated daughter products; TRU and fission products at X-705 only	Film badge or TLD, PPE, stay time, worker rotation, bioassay, ambient air flow	Moderately effective when used correctly	1958-1962 (X-344) 1957-1978 (X-705)
Buffer modification of G-17 valve	Process buildings	RAD, UF_6, HF, UO_2F_2, uranium daughters, fission products, TRU, and heat stress	Film badge or TLD, PPE, wood plugs, ventilation, bioassay	Effective when used correctly	1982-1983
Building access (to perform various duties, such as deliveries)	All Plant facilities	See full range of hazards described for all Plant facilities	Film badge or TLD, PPE, bioassay, housekeeping, postings	Minimally effective when used correctly prior to 1988 Effective when used correctly after 1988	1953-1987 1988-1997
Burial of classified and contaminated materials	X-749, X-749A	RAD, UF_6 gas, nickel carbonyl, asbestos	Film badge or TLD, PPE, stay time, bioassay	Effective when used correctly	1953-1997
Can and drum crushing	Process buildings, X-705, X-720, X-740	RAD, UO_3, TRU, technetium	Film badge or TLD, PPE, bioassay	Effective when used correctly	1997
Carpentry	Cooling towers	Asbestos, arsenic, fungicides, sulfuric acid, chromates, noise, STF, Legionnaire's Disease	PPE	Effective when used correctly.	1952-1997
Collection of uranium oxide powder from calciner	X-705	Inhalation of insoluble airborne uranium, TRU	PPE, bioassay	Moderately effective when used correctly	1954-1997

Table B-1. Portsmouth Gaseous Diffusion Plant Principal Hazardous Activity Evaluation Summary: 1952-1997 (Continued)

Activity Description	Plant Location(s)	Potential Hazard(s)	Hazard Control(s)	Hazard Control Effectiveness and Use	Time Period
Crane operation	Process buildings	RAD, PG, heat stress	PPE, bioassay	Effective when used correctly	1953-1997
Cross connection of sanitary water and contaminated condensate systems	Steam plant	RAD, ingestion or inhalation of particulates	Removal of cross-connection in early 1990s	Effective when used correctly	1979-1997
Cutting or welding Freon pipe	Process buildings, X-700	Phosgene, hydrogen chloride, burns	PPE, ventilation, Freon evacuation procedures	Effective when used correctly	1954-1997
Cylinder heel cleaning	X-705	RAD, UF_6 gas, TRU, NC, chemical burns, concentrated fission and daughter products	Film badge or TLD, PPE, bioassay, ambient air flow, cylinder net weight determination, enclosed cleaning system	Moderately effective when used correctly; beta dose to eyes not measured	1954-1997
De-blading of compressor rotor and stator	X-705	RAD, UF_6, HF, UO_2F_2, TRU, technetium, fission and uranium daughter products, noise	Film badge or TLD, PPE, bioassay, UF_6 Negative procedure, ventilation	Moderately effective when used correctly	1954-1997
Decontamination of equipment	Process buildings, X-705, X-720 instrument room	RAD, UF_6, HF, UO_2F_2, TRU, NC, PCBs, acids, solvents, uranium daughter and fission products, asbestos, chemical burns	Film badge or TLD, PPE, stay time, bioassay, ventilation, geometry, sampling, uranium mass determination	Moderately effective when used correctly	1954-1997
De-smoking ash pots through building ventilation	X-705E	RAD, TRU, HF, UF_6, UO_2F_2 contamination at building vents and release to environment	None	Ineffective	1958-1966
Disassembly of stuck shut G-17 cell block valves	X-705	RAD, UF_6, HF, UO_2F_2, TRU, fission and uranium daughter products, noise, burns, NC	Film badge or TLD, PPE, bioassay, UF_6 Negative procedure, disassembly procedure, shop evacuation, ventilation, geometry, sampling, uranium mass determination	Effective when used correctly	1955-1997
Draining cold traps	X-705E	RAD, UF_6, UO_2F_2, HF, TRU, NC	Film badge or TLD, PPE, bioassay, geometry and sampling	Effective when used correctly	1958-1978

Table B-1. Portsmouth Gaseous Diffusion Plant Principal Hazardous Activity Evaluation Summary: 1952-1997 (Continued)

Activity Description	Plant Location(s)	Potential Hazard(s)	Hazard Control(s)	Hazard Control Effectiveness and Use	Time Period
Duct maintenance	All buildings	RAD, UF_6, PCBs, fluorine, strychnine from pigeon feces due to poisoning	Film badge or TLD, PPE, bioassay	Effective when used correctly	1954-1997
Dumping uranium from vacuum collector to drums and returning uranium to process	X-344, X-705	RAD and inhalation of uranium dust	Film badge or TLD, PPE, bioassay, ambient air flow	Moderately effective when used correctly	1958-1962 (X-344) 1957-1978 (X-705)
Electrical maintenance	All	PCBs, solvents, electrocution, noise	PPE, work permits	Effective when used correctly	1953-1997
Fire box cleaning at steam plant (annual)	Steam Plant	Airborne arsenic from coal combustion	PPE, air monitoring after discovery of hazard in late 1989; only paper mask worn prior to 1989	Effective when used correctly Ineffective before 1989	1953-1997
Flange grinding	Process buildings, X-700, X-720, X-705	RAD, UF_6, HF, UO_2F_2, TRU and uranium daughter products, noise, heat, asbestos, cadmium, nickel fumes	Film badge or TLD, PPE, bioassay, decontamination, ventilation	Effective when used correctly	1954-1997
Groundskeeping	All	RAD, PCBs, asbestos, arsenic, fungicides, radioactive dust	Film badge or TLD, PPE, bioassay	Moderately effective when used correctly	1952-1997
Guard patrolling	All facilities and roads	See full range of hazards described for all Plant facilities	Film badge or TLD, PPE, contamination surveys, bioassay	Moderately effective when used correctly	1953-1997
Guard drills	All facilities and roads	See full range of hazards described for all Plant facilities	Film badge or TLD, contamination surveys, bioassay	Ineffective	1983-1995
Incinerator operations	X-705 Incinerator (New and Old)	RAD, PCB, barium, cadmium, radioactive dusts	Film badge or TLD, PPE, bioassay	Effective when used correctly	1959-1985
Industrial photography	All buildings	RAD, PG, UF_6, STF	Film badge or TLD, bioassay	Effective when used correctly	1952-1997
Instrument maintenance	X-720, X-770, and satellite instrument shops	RAD, HF, UF_6, TRU, uranium daughters and fission products, acids, mercury, solvents, burns, cyanide	Film badge or TLD, PPE, bioassay, decontamination, ventilation	Effective when used correctly	1954-1997

Table B-1. Portsmouth Gaseous Diffusion Plant Principal Hazardous Activity Evaluation Summary: 1952-1997 (Continued)

Activity Description	Plant Location(s)	Potential Hazard(s)	Hazard Control(s)	Hazard Control Effectiveness and Use	Time Period
Jetting/Venting	Process buildings	RAD, UF_6, HF, UO_2F_2, TRU and uranium daughters released to environment	Film badge or TLD, bioassay, procedures specified limiting venting to only purging cells with < 20 ppm UF_6	Effective when used correctly	1953-1997
Landfill operations	Peter Kiewit, X-734, X-735	Asbestos and ash from coal-fired plant, dust from contaminated building rubble	Administrative controls on disposal items; in early 1980s added controls on asbestos and building rubble disposal	Effective when used correctly	1955-1997
Lithium repackaging	X-740 warehouses	Lithium hydroxide monohydrate (LiOH) exposure	Respirator	Effective when used correctly	Mid-1980s
Lithium relocation	X-740 warehouses	LiOH exposure	Dust masks	Minimally effective when used correctly	1977-1980
Lubrication	All	PCBs, solvents	PPE, decontamination	Effective when used correctly	1987-1990
Machining	X-710, X-720	Lead, PG, solvents, uranium, beryllium	PPE	Effective when used correctly	1953-1997
Mercury handling	Laboratory, X-705 recovery room, X-720, process buildings	Spills, mercury vapor and contamination	PPE, containment, decontamination, ventilation	Effective when used correctly	1953-1997
Operation and maintenance of uranium recovery system (by solvent extraction and other uranium solution processing and storage)	X-705	RAD, TRU, technetium, airborne uranium, radioactive effluents, NC	Film badge or TLD, bioassay, PPE, effluents were sampled and release limits were applied, geometry and sampling	Moderately effective when used correctly	1954-1997
Plating	X-720	Cyanide, halide, ammonia, hydrogen cyanide, acids	PPE, ventilation	Effective when used correctly	1954-1997
Product withdrawal during normal operations	X-326, X-330, X-333	RAD, UF_6, TCE	Film badge or TLD, PPE, stay time, worker rotation, bioassay, ambient air flow	Effective when used correctly	1954-1997
Pulverizer operations and maintenance	X-705E, X-344	RAD and inhalation of dust containing uranium, fission products; thorium, TRU (including Np and Pu) at X-705 only	PPE, film badges or TLD, bioassay, ambient air flow	Moderately effective when used correctly	1957-1978 (X-705E) 1958-1962 (X-344)

Table B-1. Portsmouth Gaseous Diffusion Plant Principal Hazardous Activity Evaluation Summary: 1952-1997 (Continued)

Activity Description	Plant Location(s)	Potential Hazard(s)	Hazard Control(s)	Hazard Control Effectiveness and Use	Time Period
Receiving and using K-25 equipment	X-15, X-705, process buildings	RAD, UF_6, NC, HF, uranium compound deposits, TRU, technetium	Film badge or TLD, PPE, bioassay, purging, ventilation, decontamination, evacuation	Moderately effective when used correctly	1980-1997
Release response	Process and support buildings	RAD, inhalation of radioactive materials, skin contamination, chemical burns	Film badge or TLD, PPE, bioassay, ventilation, decontamination procedures, response kit	Effective when used correctly; ventilation systems were frequently inoperable	1954-1997
Removal of "000" compressors stub shaft	X-705	RAD, UF_6, HF, UO_2F_2, TRU, fission and uranium daughter products, NC, burns, noise	Film badge or TLD, PPE, bioassay, UF_6 Negative procedure, ventilation, pit evacuation, sampling, uranium mass determination	Effective when used correctly	1957-1978
Removal of compressor seals	Process buildings, X-705	RAD, HF, UO_2F_2, TRU, fission and uranium daughter products, burns, noise	Film badge or TLD, PPE, bioassay, UF_6 Negative procedure, ventilation, evacuation	Effective when used correctly	1954-1997
Removal of converter shell internal fixtures	X-705	RAD, uranium compound deposits, UF_6, HF, UO_2F_2, TRU, fission and uranium daughter products, burns, noise	Film badge or TLD, PPE, bioassay, UF_6 Negative procedure, additional purge in cell, evacuation	Effective when used correctly	1957-1993
Replacement of full UF_6 cylinder valve	X-343 X-344 X-705	RAD, UF_6, HF, UO_2F_2, TRU, fission and uranium daughter products	Film badge or TLD, PPE, bioassay, repair procedure, cooling cylinder to sub-atmospheric, and emergency response procedures	Effective when used correctly	1954-1997
Reproduction	X-100 reproduction facility	Naphtha; hydrochloric, sulfuric, phosphoric, citric, and acetic acids; ammonia; methyl alcohol; skin burns from carbon arc lamps; TCE	PPE	Effective when used correctly	1952-1997
Roof access	Various buildings	Venting HF, uranium, and other chemicals to roof	Bioassay; roof access controls implemented in X-710 in 1963	Ineffective Effective when used correctly	1954-1991 1992-1997
Sand blasting	X-744G	Silicon dioxide	PPE	Effective when used correctly	1954-1997

Table B-1. Portsmouth Gaseous Diffusion Plant Principal Hazardous Activity Evaluation Summary: 1952-1997 (Continued)

Activity Description	Plant Location(s)	Potential Hazard(s)	Hazard Control(s)	Hazard Control Effectiveness and Use	Time Period
Smelting	X-744G	RAD, HF, PG, airborne uranium, TRU, process heavy metals	Film badge or TLD, PPE, air samples, bioassay	Moderately effective when used correctly	1961-1983
Spraying cooling towers with fungicide and corrosion inhibitors	Cooling towers	Fungicides, sulfuric acid, arsenic, chromates, Legionnaire's Disease, asbestos, noise, STF	PPE	Effective when used correctly	1953-1997
Transformer maintenance	All	Electrocution, PCBs, asbestos, confined space, solvents	PPE, work permits, ventilation	Effective when used correctly	1950s-1997
Unplugging feed plant transfer lines, hoppers, and conveyers using sledge hammers and rods during normal operation	X-344	RAD, UF_6, inhalation of uranium dust, noise	Film badge or TLD, PPE, bioassay, ambient air flow	Moderately effective when used correctly	1958-1962
Unplugging fluorination towers	X-344, X-705	RAD, TRU (in X-705 only), NC, exposure to UF_6 gas, inhalation of dust containing uranium and fission products (X-705 only)	Film badge or TLD, PPE, stay time, bioassay, ambient air flow, geometry, and sampling	Moderately effective when used correctly	1958-1962 (X-344) 1957-1978 (X-705)
Uranium powder conveyer, hopper, and other equipment maintenance and replacements	X-344, X-705	RAD and inhalation of uranium dust	Film badge or TLD, PPE, bioassay, ambient air flow	Moderately effective when used correctly	1958-1962 (X-344) 1957-1978 (X-705)
Welding	Process buildings, X-700, X-720	RAD, UF_6, PG, HF, UO_2F_2, acids, uranium and fission products, asbestos, heat stress, thermal burns, phosgene, nickel fumes	Film badge or TLD, PPE, bioassay	Effective when used correctly	1954-1997

Key:

CIP Cascade Improvement Program
CUP Cascade Upgrade (or Uprating) Program
HF Hydrogen Fluoride
NC Risk of nuclear criticality
NDA Nondestructive Analysis
Np Neptunium
PCB Polychlorinated Biphenyl
PG Process gas
PPE Personal Protective Equipment (includes one or more of: respirator, shoes, gloves, caps, eye protection, ear plugs, and contamination clothing)
Pu Plutonium
RAD Includes one or more of alpha, beta, or gamma radiation
STF Slips, trips, and falls (common industrial accidents)
TCE Trichloroethene
Th Thorium
TLD Thermoluminescent Dosimeter
TRU Transuranic
Note: Bioassay includes urinalysis and/or in-vivo lung counting.